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U. S. NAVAL TECHNICAL MISSION TO JAPAN
CARE OF FLEET POST OFFICE
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17 January 1946

RESTRICTED

From: Chief, Naval Technical Mission to Japan.
To : Chief of Naval Operations.

Subject: Target Report - Japanese Electronic Tubes.

Reference: (a)"Intelligence Targets Japan" (DNI) of 4 Sept. 1945.

1. Subject report, covering Target E-13 of Fascicle E-1 of reference (a), is submitted herewith.

2. The investigation of the target and the target report were accomplished by Major Wilhelm Jorgensen, AUS.

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JAPANESE ELECTRONIC TUBES

"INTELLIGENCE TARGETS JAPAN" (DNI) OF 4 SEPT. 1945
FASCICLE E-1, TARGET E-13

NOVEMBER 1945

U.S. NAVAL TECHNICAL MISSION TO JAPAN

SUMMARY

ELECTRONICS TARGETS

JAPANESE ELECTRONIC TUBES

The report covers the construction of vacuum tubes, the development of substitute construction materials such as iron, a specific study of magnetrons and Osaka tubes, a compilation of data on the high power tubes used in the Japanese "Death Ray" experiments, and a new method for developing very high frequency radiations with moderate tube element dimensions.

A suggested research problem is brought out by the Japanese "Death Ray" experiments which indicate that high frequency radiations may possibly be used as a cure for tuberculosis and other lung disorders, as well as in treatment of brain disorders.

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LIST OF ENCLOSURES

LIST OF ILLUSTRATIONS

REFERENCES

Location of Target:

Tokyo Shibaura Electric Company.

Ninth Military Technical Laboratory.

Second Naval Technical Institute, Tokyo Branch, MEGURO.

Osaka Imperial University.

Japanese Personnel Who Assisted in Gathering Documents:

T. TAKESHITA, Lt. Col., Seventh Military Technical Laboratory.

Japanese Personnel Interviewed:

S. HAMADA, Engineer, Tokyo Shibaura Electric Company.

J. IKEBE, Engineer, Nihon Koshuha Company and Consultant, Ninth Military Technical Laboratory.

Mr. SASADA, Technician in Charge of Death Ray Experiments of Ninth Military Technical Laboratory.

Y. YASUDA, Engineer, Second Naval Technical Institute.

K. OKABE, Professor, Osaka Imperial University.

MITO, Assistant Professor, Osaka Imperial University.

INTRODUCTION

A thorough investigation of electronic tubes has been made by the Scientific and Technical Advisory Section of GHQ and by the Office of the Chief Signal Officer, SCAP, and will not be duplicated here. The following report covers some technical data on construction and use which may not be available elsewhere.

THE REPORT

The methods and materials used in the construction of vacuum tubes, the development of and specific data concerning high frequency magnetrons including a special analysis of an asymmetrical magnetron, and a special research problem concerning ultra-high frequency magnetrons by the Tokyo Shibaura Electric Company are covered in Enclosure (A).

A study by the Second Naval Technical Institute of the purification of existing materials for tube elements and the substitution of pure iron wherever possible is covered in Enclosure (B). It is claimed that the technical characteristics of pure iron were very good, but that the production of the pure iron was a more tedious and costly procedure than that of standard materials.

A study of magnetron and Osaka tubes at the Osaka Imperial University is given in Enclosure (C). Professor OKABE, the author, expressed confidence in the development of a new method of constructing still higher frequency tubes with reasonable dimensions of the tube elements by obtaining a reaction between electrons and electric waves. The professor indicated a desire to continue his research along those lines.

A list containing photographs, technical data, and names of manufacturers of the most important magnetrons and tubes used by the Ninth Military Technical Laboratory in "Death Ray" experiments is shown in Enclosure (D). An interesting point is that 12 hi-vac rotary vacuum pumps with an equal number of oil diffusion pumps are included in the equipment, though all of the tubes found were sealed-off vacuum tubes. No information could be obtained on the pumps except that they were used in making the experimental tubes. A second point of interest is that the "Death Ray" experiments showed a pronounced effect on the lungs of the animals tested, and further research was contemplated toward a possible cure for tuberculosis. It was noticed that higher frequencies affected the brain. The investigators realized that heat was an evident factor but were sure that frequency was important also. The frequency characteristic may be associated with the resonance dimensions of the head and body respectively.

In general the work listed is not new, but a few points worthy of further consideration are as follows:

1. Consideration of the medical value of ultra high frequency radiations as a means of curing tuberculosis or other types of disease.

2. Verification of effectiveness in substituting pure iron for other materials in the construction of vacuum tube elements.

3. Consideration of whether it is practicable to obtain very high frequency radiations as indicated by Professor OKABE of the Osaka Imperial University.

Magnetron and other tubes obtained from the Ninth Military Technical Laboratory that were found to have technical intelligence value by the Office of the Chief Signal Officer, SCAP, have been shipped to O. C. Sig. O., Intelligence and Communications Coordination Branch, Holabird Signal Depot, Baltimore, Md.

Samples of Osaka tubes obtained from the Osaka Imperial University have been shipped to NRL under NavTechJap Equipment No. JE50-5836.

ENCLOSURE (A)

"TUBE MANUFACTURING BY THE TOKYO SHIBAURA ELECTRIC COMPANY"
BY S. HAMADA, ENGINEER IN CHARGE

I. METHODS AND MATERIALS USED IN THE CONSTRUCTION OF VACUUM TUBES

A. The main machines and equipment involved in the manufacture of vacuum tubes in the Horikawa-Cho Works:

Name	No.
Sealex machines	6
Auto-exhausting machines	2
High frequency induction furnaces	16
Vacuum pumps	55
Basing Machines	5
Universal grid winding machines	14
National stem machines	7
Hot cut flaring machines	5
Hydrogen furnaces	35
One KVA spot welders	184
Miscellaneous	0

(Note: Factory was about 80% destroyed by bombing.)

B. Glasses and metals used for special stem tubes to prevent electrolytic phenomena on the stems of vacuum tubes such as rectifiers and small transmitting tubes:

Soda lime glass (IM-2), used for the bulbs of receiving tubes

Lead glass (R-32), used for the stem tubings of receiving tubes

Barium glass (B-814)

Boro-silicate glass (CP-34) Pyrex, used for all glass parts of the transmitting tubes

The metals used to make glass seals are popular ones such as Dumet wires for the soft glass, tungsten or molybdenum wires for the hard glass. Copper rings are used in the transmitting tubes by Housekeeper-sealing method.

C. The time required by every stage of construction of receiving tubes (example, VZ-6C6) is as follows:

Operation	Time/pc. (Theoretical)
Mounting	100 sec
Sealing	10 sec
Exhausting	10 sec
Basing	5 min
Aging	30 min
Testing	5 min
Finishing	5 min
	Total 47 min

Because of the irregular flow of operations it takes one to two days to complete one group of tubes.

ENCLOSURE (A), continued

Since the manufacture of transmitting tubes is chiefly by hand, more time is needed than for receiving tubes. For example, UV-171 (150 kw tube) takes about two weeks, SN-205C five days, HV-969 (Hg.) four days.

Time for degassing and evacuation:

Receiving tubes		70 - 150 sec
Transmitting tubes	(UV-171)	100 hours
	(SN-205C)	8 hours

D. The popular method of degassing is to heat the metal parts to 900-1300°C in a high frequency induction furnace utilizing eddy currents losses. 30-90 seconds heating time is usually sufficient but sometimes five minutes are required.

Carbon anode tubes and large tubes are degassed by electron bombardment, which requires a longer time.

E. <u>Materials used in filiments</u>:

Direct heated:	Tungsten (Wolfram) wires Thoriated tungsten wires Nickel wires Konel flat wires (cobalt, nickel) No. 16 metal flat wires
Indirect heated:	Nickel sleeves Tungsten wires Tungsten-molybdenum wires
Emission coatings:	Barium-strontium double carbonates Ba-Sr-Ca triple carbonates Organic solvents (Amyl acetate, Butyl acetate and Nitrocellulose)

F. <u>Materials used in grids</u>:

Side rods:	Nickel wires Copper wires Ni-plated Cu wires Ni-plated iron wires
Side rods and grid wires:	Molybdenum wires
Grid wires:	Manganese nickel wires Invar wires Nichrome wires
Special grids:	Tantalum wires

G. <u>Materials used in plates</u>:

Nickel strip
Nickel plated iron strip
Iron strip
Graphite
Molybdenum plate
Copper
Tantalum plate
Monel plate

H. **Methods used to maintain vacuum:**

Barium metal-clad
Barium-aluminum alloy
Barium-aluminum-nickel alloy
Barium-magnesium alloy
Barium-strontium carbonates on tantalum wire
Barium-berylliate on molybdenum wire
Magnesium metal

I. **Methods used to activate filaments:**

Oxide filaments: Decomposition is accomplished by heating the filament or the cathode in low vacuum to 400 to 800°C for about 10 to 50 seconds.

Activation is accomplished by keeping the temperature of filament or cathode at 800-1100°C in high vacuum. After the getter is flashed and tube is tipped off, the filament or cathode is heated once more at moderate temperature about 10-20 minutes.

Thoriated tungsten filaments: The flashing temperature of 2800°K is is maintained for 30-60 seconds; the activation temperature is 2200-2300°K, which is maintained for 30-120 minutes.

J. **Annealing of transmitting tubes:**

Stem annealing: 550°C max. for 90 min. in an electric oven.

Bulb annealing: With gas flame at sealing operation.

K. **Tests before shipping:**

Factory tests of electric characteristics (100%) and of appearance are given.

Laboratory tests are of electric characteristics (daily pick up) and life. (Aging load: Normal load or 50% overload ; Time (Weekly pick up.)

The customer test is similar to the factory tests.

II. MAGNETRON DATA

A. **Brief Sketch of Magnetron Development** - Development of magnetrons was started in 1932 by the late K. KAMINO in the Tokyo Shibaura Electric Company. He developed mainly two-split magnetrons of both air and water cooled type. Since 1935 magnetron oscillators of high efficiency and larger power output have been investigated by S. HAMADA, T. SHIMIZU and others who developed several types of tubes whose principal specifications are given in the following pages. In 1936 three kinds of 4-split graphite anode types were developed the MX-1, MX-2, and MX-3. To eliminate construction difficulties in multi-split magnetrons, an asymmetrical split-anode type was developed in 1937, a typical tube being MAX-1. Between then and the end of the war attempts were made to obtain a larger output at wave lengths below 20cm. 8-split and 12-split types were successful: an output of over 200 w at 20cm was obtained by the 12-split molybdenum anode magnetron MV-14. In 1934, over 500 w was obtained experimentally at this wave length by a tube whose electrodes were

ENCLOSURE (A), continued

of larger dimensions than those of MV-14. For wave lengths below 10cm, all-metal type magnetrons were studied simultaneously. A few experimental tubes obtained in the laboratory in the beginning of 1945 gave fairly good results.

B. Technical Description of Magnetrons Manufactured by the Company

(1) Principal Dimensions and Operating Conditions, Graphite Anode Magnetrons:

	MX-1	MX-2	MX-3	MX-1
Anode diameter	0.4cm	0.8cm	1.5cm	0.37cm
No. of splits	4	4	4	Asymmetrically split
Wave length band available (cm)	15-35	35-100	50-150	16-24
Anode voltage (max.)	1500	2000	2500	1500
Strength of magnetic field (gauss)	1500	650	400	2000
Power output watts (at wave length)	20 (20cm)	100 (50cm)	200 (100cm)	20 (20cm)

(2) Principal Dimensions and Operating Conditions, 8-Split and 12-Sp Molybdenum Anode Magnetrons:

	MX-4	MV-14
Anode diameter (cm)	0.8	1.2
Cathode diameter (cm)	0.28	0.55
Anode axial length (cm)	0.8	1.5
No. of splits	8	12
Wave length available (cm)	20	20
Anode voltage (volts)	2000	2500
Anode current (ma)	150	200
Magnetic field (gauss)	1500	1200
Power output (watts)	100	200

(3) Principal Dimensions and Operating Conditions, 12-Split Molybdenum Anode Magnetrons:

	MP-20	MP-15
No. of splits	12	12
Anode diameter (cm)	1.7	12
Cathode diameter (cm)	0.85	0.6
Wave length (cm)	20	14.6
Anode voltage (volts)	8-10	8-10
Peak power output (kw)	2.5-3.0	2-2.5

(4) List of Tubes Available at 150cm and above:

I. Magnetron			II. Triode				
Name of Tube	Use	Wave Length Available cm	Name of Tube	Anode Voltage kv	Wave Length cm	Power Output mw	Cooling
MX-1	Transmitting	15-35	T-327	6	27	2	Natural
MX-2	Transmitting	35-100	T-324	10	150	20	Forced Air
MAX-1	Transmitting	20	T-321	8	60	5	Natural
MV-14	Transmitting	20	SY-5	8	150	20	Natural
MP-20	Transmitting	20	SN-7	6	50	5	Natural
MP-15	Transmitting	14.6					
MOX-1	Receiving	20*					
Metal seal type	Transmitting	10					

ENCLOSURE (A), continued

*OSAKA tube invented by OKABE. Looks interesting. Barkhausen Kurtz oscillator. Used as detector in dcm band.

C. <u>Asymmetrical Magnetron of the Company</u>

(1) The asymmetrical magnetron is a magnetic field tube whose anode is unsymmetrically split in the direction of the cathode. Electron oscillations of high order can easily be generated by a tube having such electrode arrangements.

(2) In Figure 1, let θ_1, θ_2 be the angles subtended by A_1, the smaller segment, and A_2, the larger segment of the anode, respectively.

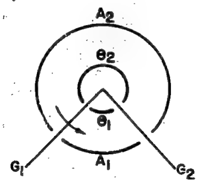

Figure 1(A)

ASYMMETRICAL MAGNETRON

(a) Then, let $m = \frac{\theta_2}{\theta_1}$ .... (1)

where m is defined as the degree of asymmetry in the asymmetrical magnetron.

In general, $\theta_2 = \theta_1$, that is, $m = 1$,.

The conditions necessary and sufficient to the production of an electron oscillation of higher order in such an electrode arrangement are:

(i) The ratio of transit time of an electron from the gap G_1 to G_2, to the period of generated oscillation should not be an integer.

(ii) The ratio of transit time of the above electron travelling along the anode from the gap G_1 and coming back again to the same spot, to the period of generated oscillation, should be an integer.

The ratio of transit time for the above electron travelling along the anode from the gap G_1 and coming back again to the same spot, to the period of generated oscillation should be an integer.

(b) Let $\theta_1 = \frac{\pi}{p}$

where p is the number of segments in the symmetrically split magnetron which can generate the same frequency as the asymmetrical magnetron. Then the above conditions may be written as

$$\frac{2\pi p}{m+1} \neq 2\pi a$$

in which "a" may be any integer and therefore,

$$\frac{p}{m+1} \neq a \text{ .... } (2)$$

(c) An electron oscillation of higher order can be generated when condition (2) is fulfilled. For instance, it may be known that the oscillations corresponding to p = 2, p = 4, and so forth, which are usually generated by the symmetrical 4-split and 8-split magnetrons, can be generated by the tube having m = 1, that is, symmetrical 2-split magnetrons. In this case, the generated frequency is expressed as

ENCLOSURE (A), continued

$$\frac{Kr_a^2 H}{p V_a} \text{ ....(3)}$$

where r_a = radius of anode in cm, H = field strength in gauss, V_a = anode voltage, p = number of pairs of pole, and K = constant, approximately 1000. The equation (3) is the same as in the case of symmetrical multi-split magnetrons. For the asymmetrical magnetron having $m = 2$ or $\theta_1 = \frac{2}{3}\pi$, we can generate besides the fundamental wave length corresponding to p = 1 the higher harmonic oscillations corresponding to p = 2, p = 4, p = 5 and so forth. It is impossible, however, to obtain the third, the sixth, and similar harmonic waves.

(d) From the foregoing statements it can be deduced that with any asymmetrical magnetron whose "m" satisfies condition (2) we can generate the fundamental wave length of a symmetrical two-split magnetron having the same diameter, anode voltage, and strength of magnetic field.

By inserting the proper resonance circuit into the tube, we can obtain fairly stable oscillations similar to those in the case of a symmetrical multi-split magnetron.

III. MAGNETRON RESEARCH PROBLEM CONDUCTED BY THE COMPANY (H. IMAI)

A. CM Magnetron Specifications

(1) 5cm

Ep .... 10,000 V
Ef .... 11 V
B .... 1000 gauss
If 1.4A
Peak output .... 3 kw
Maximum plate dissipation .... 100w (natural cooling)
Magnet pole gap .... 1 5/16"
Overall length .... 6"

(2) 3cm

Ep .... 12,000 V
Ef .... 11 V
B .... 800 gauss
If 1.6A
Peak output .... 1 kw
Maximum plate dissipation .... 30w (natural cooling)
Magnet pole gap .... 1 5/16"

B. Equipment Using Centimeter Magnetrons - Using these magnetrons, we engaged in fundamental research concerning PPI which can be applied not only to the usual range of 50 km but to a very short distance up to 15 meters. The latter is especially important for taking panoramic views in the case of blind landings or group flight in fog. Because of the sharp beam, the decrease in revolving radiator size, and the extremely short pulse duration required for such an application we aimed at equipment described as follows:

(1) Oscillator: 5cm magnetron later superseded by one of 3cm.

(2) Feeder: Rectangular wave guide common to transmission and reception; coaxial pipes partially used in the valve outlet and in the retating mechanism.

ENCLOSURE (A), continued

(3) Radiator: Split antenna on one face of cavity resonator located in the focus of parabolic mirror.

(4) Modulator: Pulse duration 0.05 MS for short distance, 2 MS for long distance.

(5) Receiver: Mixer, crystal detector.
Focal oscillator velocity modulated tube.
I.F. mid-frequency 150 MC/S.
Band width 40 MC.

(6) Indicator:

(a) Braun tube, rotating radial sweep.

(i) Repeating frequency 80 kc/s for short distance, 2 kc for long distance.
(ii) Rotating frequency: About 10 c/s synchronous with mirror revolution.

(b) Besides the PPI, we intended by applying the above mentioned principles to get an advanced detector for ships or submarine periscopes.

(c) PPI Indicator: For the PPI described in paragraph 2 we used the ordinary 12" diameter Braun tube (cathode ray), although this was not specially designed for long fluorescent time. Such a specially designed Braun tube was not yet in mass production in our factoryand revolution of the mirror as fast as 10 C/S seemed to be not so difficult from the viewpoint of mechanical design. Instead of the selsyn motor widely used to generate the revolving radial sweep, we adopted an optico-electrical method, the principle of which is as follows:

(i) Two sets of light sources and corresponding photo-cells are set perpendicular to each other in the plane which is perpendicular to the revolving mirror (antenna) shaft. To the shaft, two cams are fitted each of which cuts the corresponding light beam as the shaft revolves so as to generate sinusoidal waves in the photo-cell. It is obvious that the generated waves differ by exactly 90° in phase, notwithstanding the revolution speed of the shaft.

(ii) By modulating the repeating frequency with these waves and cancelling the carrier repeating frequency independently, two modulation product voltages are supplied to the vertical and horizontal deflecting plates respectively and we obtain the desired revolving pattern. Contrary to the difficulty met with a selsyn motor, 80 kc, we can easily select the repeating frequency and the images of the objects to be detected in all directions around the detector can be seen at a glance upon the Braun tube.

(d) The harmful image of a fixed object, such as a mountain, cannot be rejected from the indicator when the impulse method is used in a radio locator. But if the Doppled principle is applied we can detect a moving object of high speed only and can measure, furthermore, the absolute velocity of the object. The demerits of the latter lie in the fact that it is difficult to get the stable, noiseless, continuous decimeter waves of high power and to measure the distance at

ENCLOSURE (A), continued

direct reading. The outline of the locator, developed through much difficulty in the Research Laboratory under H. IMAI, the writer of this report, is as follows:

Wave length	20cm
Transmitter	12-split magnetron (air cooled)
Antenna output	150 w (continuous)
Detector	Crystal
Mirror diameter	2.5 meters
Range finding system	F.M.
Effective distance	25 km for medium bomber
	40 km for B-29

The locator did not come into actual use.

ENCLOSURE (B)

"STUDY OF MATERIALS USED IN THE CONSTRUCTION OF VACUUM TUBES"
BY Y. YASUDA
SECOND NAVAL TECHNICAL INSTITUTE, TOKYO BRANCH. MEGURO

I. Introduction

Most of the materials used for vacuum tubes, for example molybdenum and nickel, are not produced in sufficient quantities in Japan, and the current materials have many defects to be corrected or eliminated. Accordingly we investigated improvements for current materials and substitutions for them.

II. Improvement of Current Materials

A. Heat Treatment of the Mo Anode - The production yield of Mo anodes in pounding and bending operations was fairly low as a result of unsuitable annealing conditions. The annealing condition of Mo plates was studied and the following conditions (see Figure 1(B)) were found which resulted in remarkably increased production efficiency.

B. Improvement of Manufacturing Conditions of Mo-W (Molybdenum-Tungsten) and Th-W (Thorium-Tungsten) Wires - Mo-W and Th-W wires which are used in several components of the tubes, for example glass sealing wire (W, Mo), grid wire (Mo), heater wire (W, Th-W) etc., give very poor yields for making tubes as a result of the difficulties of working the wires and of the defects which frequently appear on the surface of the wire. Therefore by investigating in detail the manufacturing procedure of every factory the quality of the products has been greatly raised by making the following improvements:

1. Production of metal powders
   (a) Improving the purity of WO_3: doping is indispensable.
   (b) Improving the purification of H_2 gas and the control of its flow by the reduction process.
   (c) Improved regulation of the powder sizes.
2. Forming (Pressing) operations
   (a) Increase of forming pressures to at least 2 ton/cm^2.
3. Sintering operations
   (a) Measuring the fusion current at all times.
   (b) Maximum sintering current maintained above 90% of the fusion current (in the case of W, about 92%).
4. Swaging operations
   (a) Swaging temperature (first swaging) maintained as high as possible, at least 1600°C.
   (b) Retreating accomplished between first and second swaging.

III. Study of Substitution Materials

A. Pure Iron - Because of the shortage of the formerly used Mo and Ni, the tube elements had to be made from iron. For this purpose the production of pure iron was studied since materials used for tube elements must contain as

ENCLOSURE (B), continued

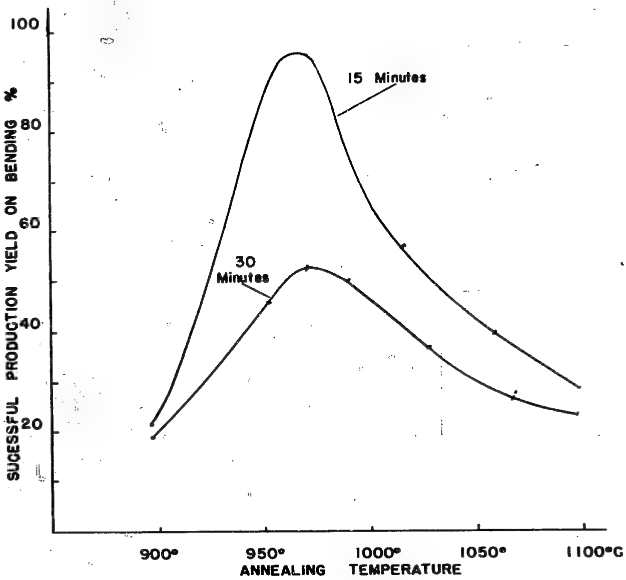

Figure 1(B)

VARIATION IN YIELD CHARACTERISTICS OF MOLYBDENUM BY DIFFERENT ANNEALING TEMPERATURES

ENCLOSURE (B), continued

little gas as possible.

1. Production and purity - Iron was produced in an electric arc furnace from iron sand. The raw iron thus made was remelted by a high frequency electric furnace and was deoxidized sufficiently with Si and Al to result in the composition given below:

C	0.02
Si	0.15
Mn	0.03
P	0.02

S	0.02
Cu	0.2
Al*	70.1
O_2	0.02

*Note: Al must be above 0.1% for perfect deoxidation and the O_2 content is usually below 0.02%.

2. H_2 heat treatment - The sheet and wire made from the above mentioned pure iron must be treated in a H_2 (hydrogen) stream at 1100°C for two hours before being used for any part. (For large power tubes this treatment is indispensable, although for small receiving tubes it is not necessary.) By this treatment, the gas content of the iron (particularly O_2) is remarkably decreased. (See Figure 2(B)).

The higher the treating temperature the shorter the required treating time, but temperatures above 1100°C are not easily attained in practice.

(a) The analysis of the gas emerging from pure iron at high temperature is as shown in Table I(B). The most harmful gas, O_2, is removed by H_2 treatment.

TABLE I(B)

QUANTITY OF GAS EVOLVED FROM IRON AT HIGH TEMPERATURES

	at 850°C cc/100g	at 1050°C cc/100g	total cc/100g
Commercial pure iron	3.54	9.67	13.21
Our pure iron	3.89	0.57	4.46
After H treatment	0.60	0.46	1.06

(b) The time required for the degassing operation of a tube whose anode is made from the above mentioned pure iron is shown in Table II(B).

TABLE II(B)

COMPARATIVE TIME OF DEGASSING REQUIRED FOR DIFFERENT ANODE METALS

	Time of anode degassing	Time of total degassing
Commercial pure iron	40 min	120 min
Our pure iron	30 min	60 min
Mo anode	30 min	60 min

(c) Electron emission and durability of our pure iron is not inferior to that of Mo or Ni tubes.

B. Deoxidized Cu and Cu-Ag Alloys - The copper used previously for the anode and other portions of the tubes had the defect of being unsatisfactory

ENCLOSURE (B), continued

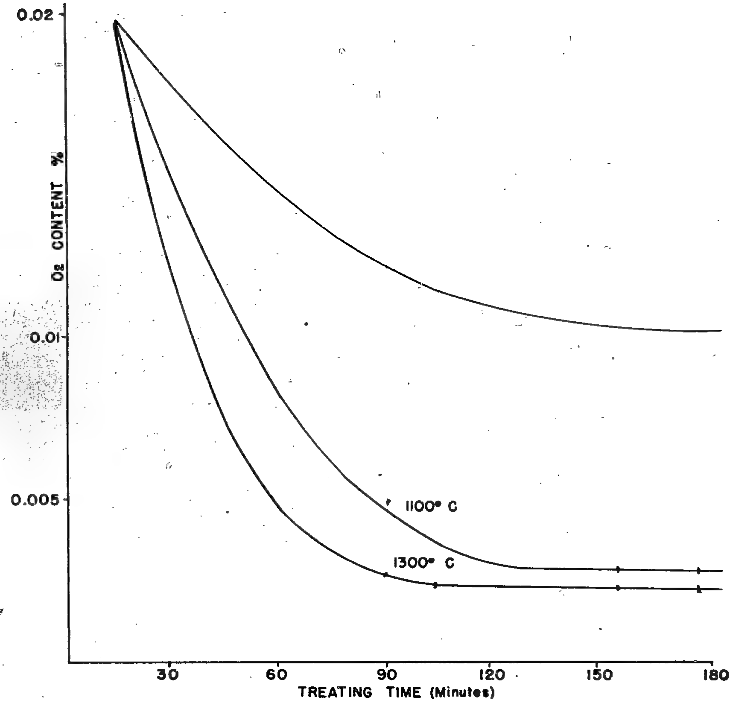

Figure 2(B)

REMOVAL OF O_2 FROM FE AT HIGH TEMPERATURES

to weld to the glass and of discharging gas at high temperatures during operation. But by passing the molten Cu through a layer of heated charcoal it was deoxidized sufficiently to produce a marked improvement in the production yield. Moreover, for the portions of the tubes which require more hardness and minute working, we used 2% Ag containing Ag-Cu alloys in place of Cu and obtained equally good results.

TABLE III(B)

OXYGEN CONTENT OF CU AND CU-AG ALLOYS USED FOR VACUUM TUBES

	Cu	Ag	O_2 content
Market Cu	99.6		0.03 - 0.04
Studied Cu	99.95		0.002
Ag-Cu alloy	97.9	1.97	0.002

C. Sleeve Nickel - Since monel nickel used prior to this time for the cathode sleeves of radio tubes was not available, the substitution of electrolytic nickel was necessary. We studied the melting of electrolytic nickel in a high frequency electric furnace, passing CO gas into the molten metal and deoxidizing sufficiently with Mg. By this method we obtained an electrolytic Ni sleeve not inferior to the monel sleeve. Moreover we discovered that nickel containing 0.2-0.3% Mg had far more electron emission than ordinary nickel.

D. "Getter" Plate - The above mentioned pure iron was used for "getter" plates in place of Ni with complete success.

ENCLOSURE (C)

"MAGNETRONS AND OSAKA TUBES"
BY K. OKABE,
OSAKA IMPERIAL UNIVERSITY

A. Our work consisted primarily of the theoretical design of ultra-high frequency radio and radar tubes, such as the magnetron and the Osaka tubes, with the purpose of producing, detecting and amplifying ultra-high frequencies. Our work attempted to show the principles of tube operation, while the problems of construction, application, and durability were left to the tube manufacturers. A list of researches conducted on ultra-high frequency radio and radar type tubes as follows:

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17. On the Amplitude Modulation of B-Type Oscillation in OWAKI: Rep. Kawanishi Kikai.

ENCLOSURE (C); continued .

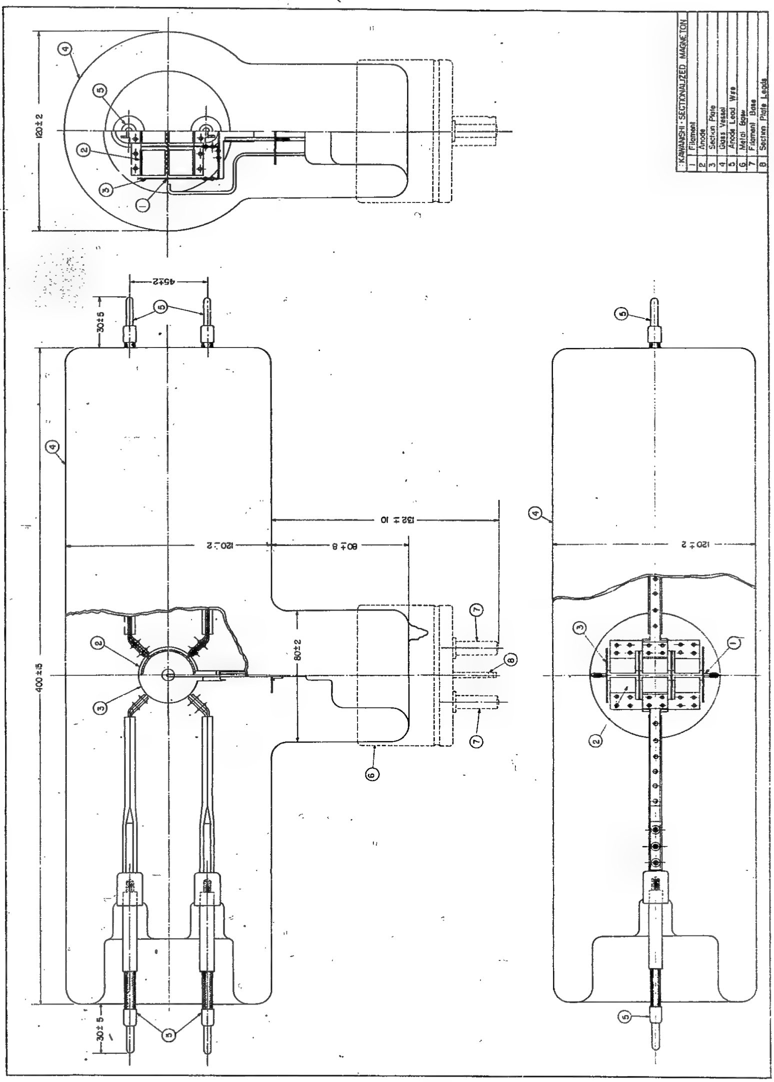


Figure 1(C)

ENCLOSURE (C), continued

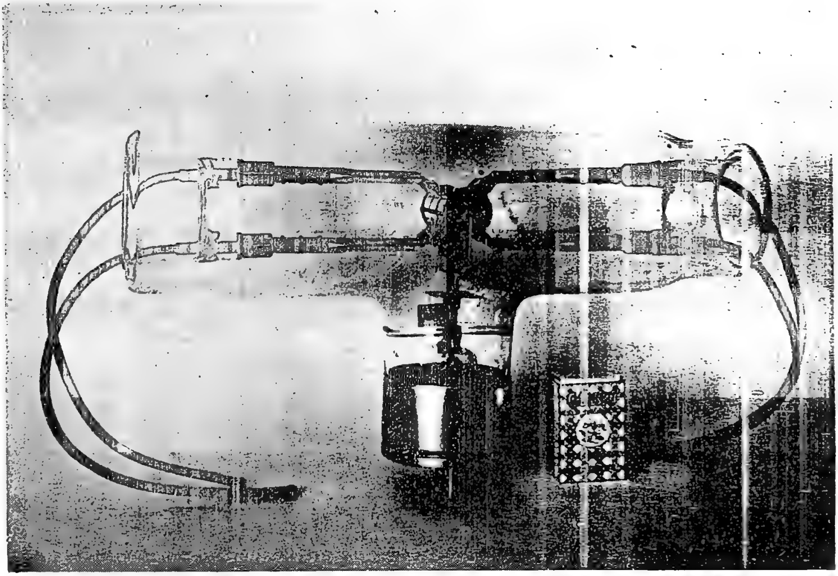
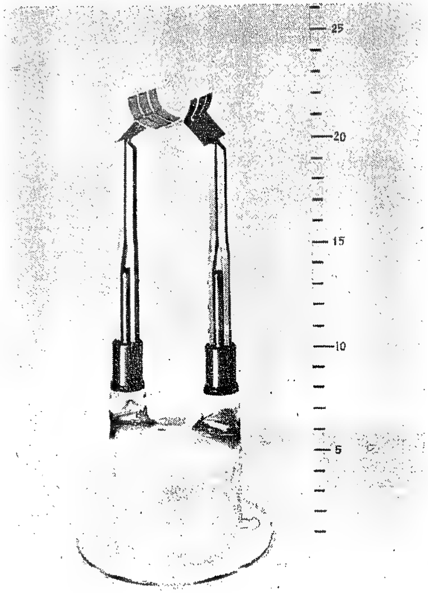
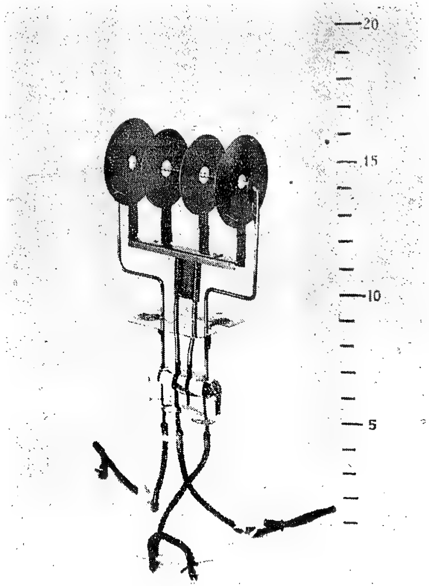


Figure 2(C)
SECTIONALIZED MAGNETRON
150 mc, 1 KW (CW)

ENCLOSURE (C), continued



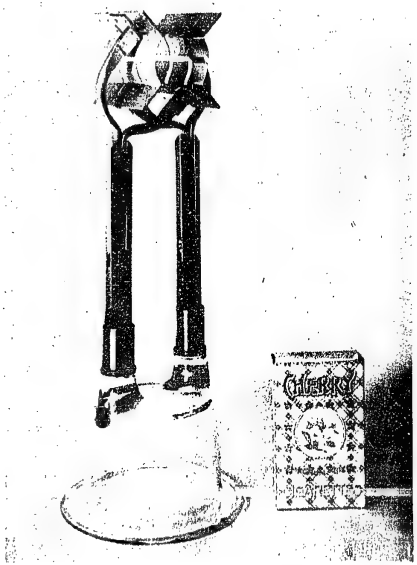
i - Anode Elements



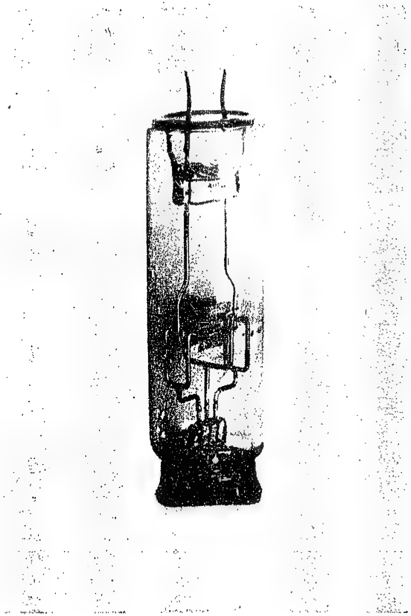
ii - Sectionalizing Plates and Filament (Cathode)

Figure 3(C)
TUBE ELEMENTS (SECTIONALIZED MAGNETRON)

ENCLOSURE (C), continued



i - Anode. Sectionalized Magnetron



ii - Osaka Tube

Figure 4(C)
SECTIONALIZED MAGNETRON ANODE AND OSAKA TUBE

ENCLOSURE (C), continued

18. On the Internal Impedance of Magnetron. KOTANI: Not Published.

19. Electron Trajectories in Magnetron. KOTANI and MIYAJIMA: Not Published.

B. <u>Design and Construction Characteristics of the Magnetron and Osaka Tube</u>

1. The filaments of magnetrons used generally in Japan are of the single spiral types. Some designers considered multiple filaments, but I have never seen any in practice. Such tubes probably will be very difficult to use and probably will lack stability. According to Mr. T. ODADA (engineer at the Nihon Musen Co.) the best results are obtained when the ratio of the anode to the cathode diameters is approximately three. The construction details of a sectionalized magnetron are shown in Figure 1(C). Other constructions are shown in Figures 2(C) to 4(C)i inclusive.

2. Oxide coating of the filaments gave high emission rate for impulse type oscillations but made very little difference in case of continuous oscillations.

3. The plates, Figure 3(C)ii, were inserted to prevent electrons bombarding the glass surface and causing tube failures. Sectionalizing the magnetron along its axis increases efficiency by limiting excessive undesirable axial motion in the electrons. The late K. KAMIO (engineer at the Tokyo Denki Co.) reported to me that the maximum efficiency of the electron magnetron was higher than 80% at wave lengths of approximately one meter (CW). As far as I am aware, no experimental production of impulse oscillations with this tube has been attempted.

4. The Osaka tube (see Figure 4(C)ii) has curved anode plates to obtain a parabolic field in the direction of H. It is noteworthy that the Osaka tube is comparable in its characteristics to the split anode magnetron. [More complete data on the operation of the Osaka tube can be found in NavTechJap Report, "Japanese Electronics - General," Index No. E-28.]

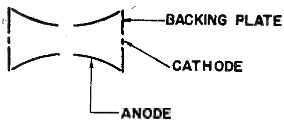


Figure 5(C)

SCHEMATIC SKETCH OF THE ELEMENT STRUCTURE OF THE OSAKA TUBE

C. <u>Other Research</u> - A few years ago we tried to produce very short wave length oscillations by utilizing the mutual reaction between electron and electric wave, instead of utilizing that between electron and H.F. electric field as in the cases of magnetron and V.M.T., etc., (see Enclosure (E), "A Method of Producing Electric Waves of Very Short Wave Length" by K. OKABE). The aim of the present research was to obtain intense cm or mm waves without making the dimensions of the electrodes as small as in the cases of magnetron and V.M.T., etc., but we could not continue this research because of the war.

ENCLOSURE (D)

"MAGNETRONS AND OTHER VACUUM TUBES USED BY THE NINTH MILITARY TECHNICAL LABORATORY IN DEATH RAY EXPERIMENTS"
DATA BY J. IKEBE,
ENGINEER AT NIHON MUSEN AND TECHNICAL ADVISOR ON RESEARCH

A. Photographs of the tubes are shown in Figures 1(D) through 6(D) inclusive. The technical characteristics and the manufacturers are listed in Table I(D).

B. All of the tubes were turned over to the Signal Officer, Office of the Chief Signal Officer, SCAP, for further study. Those tubes found to have intelligence value were shipped to O.C. Sig. O. Intelligence and Communication Coordination Branch, Holabird Signal Depot, Baltimore, Maryland.

C. The tubes E-25 and E-26, Figure 4(D)ii, were listed as simple triodes, but appear to be electron-beam magnetrons.

D. The experimental apparatus had been dismantled and destroyed, but according to reports, the power taken from the magnetrons was fed into a parallel wire or coaxial transmission line, tuned externally, and from there the power was delivered to a dipole radiator near the focus of a parabolic mirror reflector.

E. A large multiple segment magnetron, designed to deliver 100 kw CW output at approximately 400 mc, was in the process of development when the war ended, but the remains of the partially completed magnetron were thrown in Lake KIZAKI. A template model of the high power magnetron was at the Tokyo Technical College in the hands of the designers, Prof. K. MORITA and Asst. Prof. M. NISHIMAKI of the College. It was intended to connect ten of these magnetrons in parallels to obtain 1000 kw (CW) output but details had not been worked out. For further details see the report "Scientific Intelligence Survey in Japan" by the Scientific and Technical Advisory Section, GHQ, U.S. AFPAC.

ENCLOSURE (D), continued

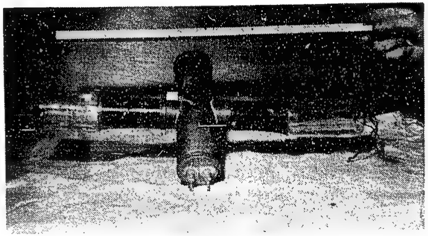
TABLE I(D)

VACUUM TUBES USED BY THE NINTH MILITARY TECHNICAL
LABORATORY IN DEATH RAY EXPERIMENTS
J. IKEBE - NIHON KOSHUHA COMPANY

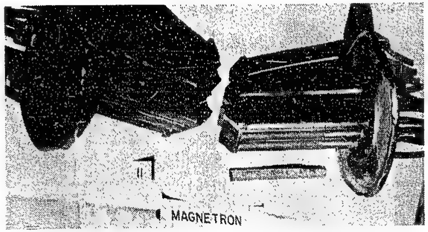
Figure	No	Type	Frequency	Power		Anode Voltage	Maker	Mag. Field Gauss
				Peak	CW			
1(D)i	E-11	Plate Elements for E-22						
1(D)ii	E-22	Magnetron	250 mc		20 kw	3000	Kawanishi	800
1(D)ii	E-22A	Magnetron	250 mc		20 kw	3000	Kawanishi	800
1(D)ii	E-22B	Magnetron	250 mc		20 kw	3000	Kawanishi	800
1(D)iii	E-20	Magnetron	430 mc		5 kw	7000	Kawanishi	1100
1(D)iv	E-21	Magnetron	200 mc		20 kw	4000	Kawanishi	700
2(D)i	E-1	Magnetron	750 mc		30 w	2000	Kawanishi Koba	900
2(D)ii	E-2	Magnetron	500 mc		30 w	2000	Tokyo Shibaura	900
2(D)iii	E-7	Magnetron	3000 mc	10 kw	30 w	7000	Nihon Radio Corporation, TOKYO	1000
2(D)iv	E-6	Magnetron	750 mc		50 w	7000	Sendai Imperial University	1500
2(D)v	E-8	Magnetron	250 mc		200 w	5000	Kawanishi	900
2(D)vi	E-10	Magnetron	3300 mc		50 w	2000	Kawanishi	1200
3(D)i	E-4	Magnetron	500 mc		60 w	3000	Nihon Musen	1200
3(D)ii	E-23	Magnetron	1500 mc		100 w	2000	Nihon Radio Corporation, TOKYO	900
3(D)iii	E-24	Magnetron	190 mc		500 w	4000	Kawanishi	750
3(D)iv	E-9	Magnetron	1500 mc		200 w	3000	Tokyo Shibaura	1000
3(D)v	E-3	Magnetron	500 mc		60 w	2000	Tokyo Shibaura	800
3(D)vi	E-6	Magnetron	750 mc		50 w	7000	Sendai Imperial University	1500
	E-5	Magnetron	500 mc		100 w	4000	Kawanishi	850
4(D)i	E-12	Triode - Power Amp				350	Sumitomo	
4(D)ii	E-25	Triode	75 mc		4 kw	7000	Sumitomo	
4(D)ii	E-26	Triode	60 mc		60 kw	20000	Sumitomo	
4(D)ii	E-26A	Grid head for E-26 type Triode*						
4(D)ii	E-26B	Grid for E-26 type Triode*						
4(D)ii	E-26C	Same as E-26*						
4(D)ii	E-26D	Grid and Filament for E-26 type Triode*						
4(D)iii	E-13	Triode	200 mc		200 w	2000	Tokyo Shibaura	
4(D)iv	E-42	Triode - Power Amp				1500	Nihon Musen	
4(D)iv	E-43	Triode						
5(D)i	E-34	Kenetron		50M amp**		70000V Inverse	Tokyo Shibaura	
5(D)ii	E-18	Kenetron		10 amp**		20000V Inverse	Tokyo Shibaura	
5(D)iii	E-36	Kenetron		10 amp**		20000V Inverse	Tokyo Shibaura	
5(D)iii	E-35	Kenetron		10 amp**		20000V Inverse	Tokyo Shibaura	
	E-17	Kenetron		10 amp**		20000V Inverse	Tokyo Shibaura	
	E-19	Kenetron		30 amp**		20000V Inverse	Tokyo Shibaura	
5(D)iv	E-14	Thyratron - High speed relay					Tokyo Shibaura	
6(D)i	E-16	STV 280/40						
6(D)ii	E-27	Triode	200 mc	100 w	3 w	2000	Tokyo Shibaura	
6(D)ii	E-28	Triode	3 mc		10 w	800	Nihon Musen	
6(D)ii	E-29	Triode B.K.O. sc	150 mc	Few micro watts				
6(D)ii	E-30	Triode	200 mc	5 kw	200 w	4000	Sumitomo	
6(D)ii	E-31	Triode	200 mc	4 kw	150 w	5000	Tokyo Shibaura	
6(D)ii	E-32	Triode	150 mc		200 w	4000	Nihon Musen	
6(D)ii	E-33	Triode	150 mc		400 w	5000	Nihon Musen	
6(D)iii	E-15	Low voltage discharge valve				150	Tokyo Shibaura	
6(D)iv	E-41	Local Osc. Magnetron (found at Second Naval Technical Institute						

* May be electron beam magnetrons.
** Peak plate current

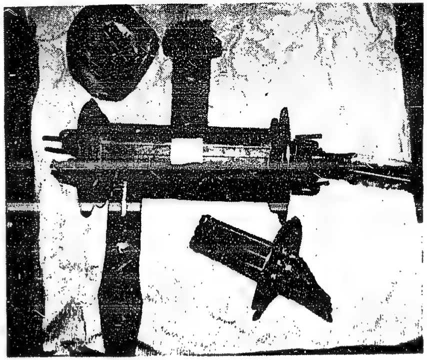
ENCLOSURE (D), continued



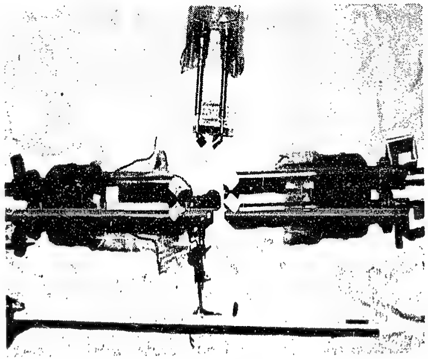
i – E-11 250 mc 20 KW Kawanishi



iii – E-20 430 mc 5 KW Kawanishi



ii – E-22 250 mc 20 KW Kawanishi

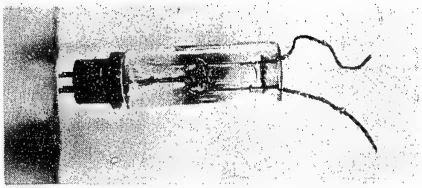


iv – E-21 200 mc 20 KW Kawanishi

Figure 1(D)

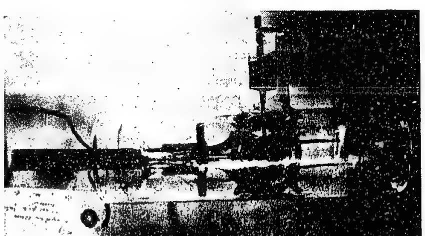
HIGH POWER MAGNETRONS (NINTH MILITARY TECHNICAL LABORATORY)

ENCLOSURE (D), continued

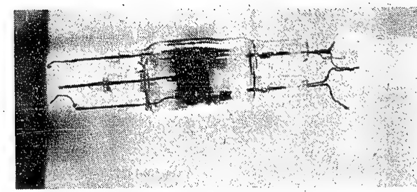


i – E-1 750 mc 30 W Kawanishi Koba

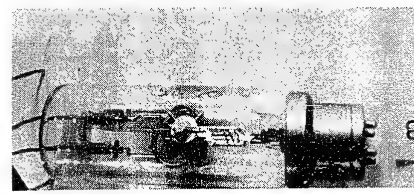
ii – E-2 500 mc 30 W Tokyo Shibaura



iii – E-7 3000 mc 300 W (10 K to peak) Nihon Radio



iv – E-6 750 mc 50 W Sendai Imp. Univ.

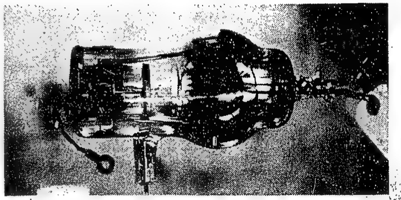


v – E-8 250 mc 200 W Kawanishi Magnetron

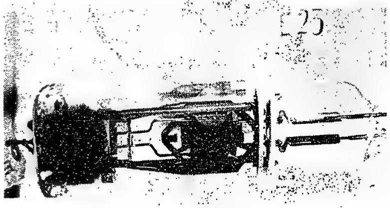
vi – E-10 3300 mc 50 W Kawanishi Magnetron

Figure 2(D)
MAGNETRONS (NINTH MILITARY TECHNICAL LABORATORY)

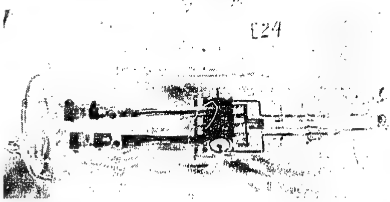
ENCLOSURE (D), continued



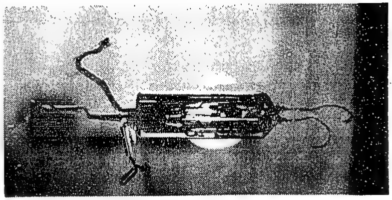
i – E-4 500 mc 60 W Nihon Musen Magnetron



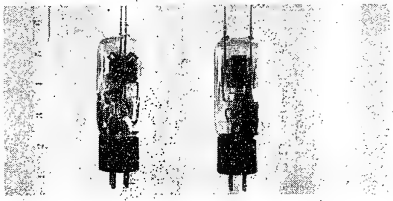
ii – E-23 1500 mc 100 W Nihon Musen Radio Corp.



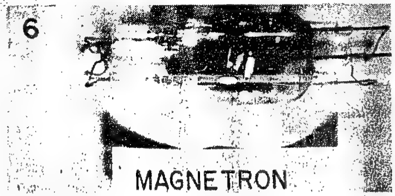
iii – E-24 190 mc 500 W Kawanishi Magnetron



iv – E-9 1500 mc 200 W Tokyo Shibaura Magnetron



v – E-3 500 mc 60 W [illegible] Magnetron

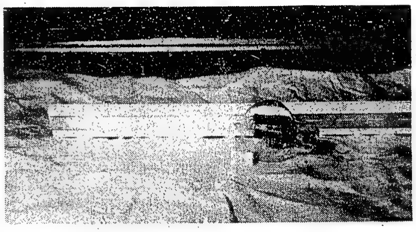


vi – E-6 750 mc 50 W Sendai Imp. Univ. Magnetron

Figure 3(D)

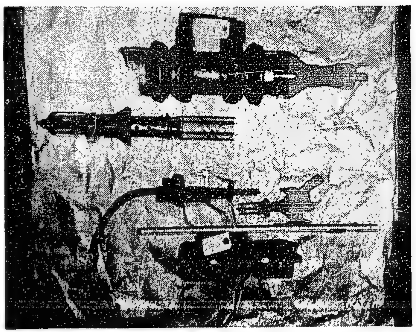
MAGNETRONS (NINTH MILITARY TECHNICAL LABORATORY)

ENCLOSURE (D), continued



i - E-12 Triode Power Amplifier - Sumitomo

iii - E-13 200 mc 200 W Tokyo Shibaura Triode



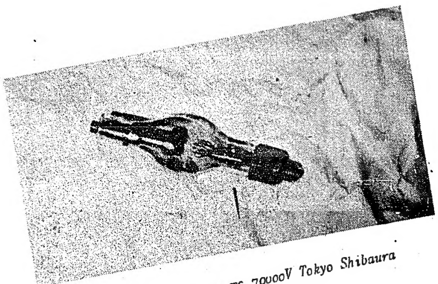
ii - E-25 75 mc 4 KW Sumitomo Triode
E-26 60 mc 60 KW Sumitomo Triode

iv - E-42 Nihon Musen Triode Power Amplifier
E-43 Nihon Musen Triode

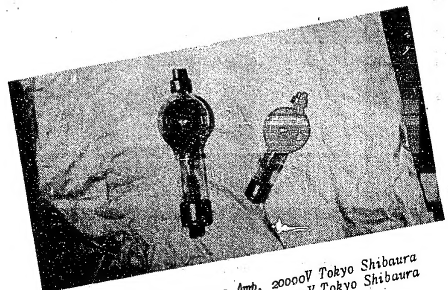
Figure 4 (D)

TRIODES (NINTH MILITARY TECHNICAL LABORATORY)

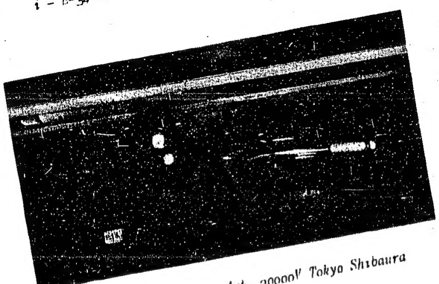
ENCLOSURE (D), continued



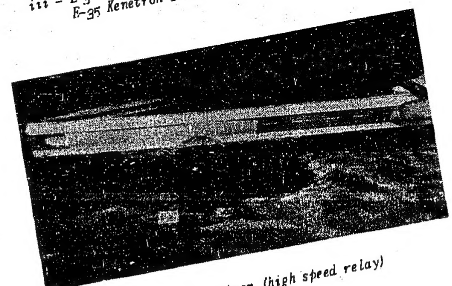
i - E-34 Kenetron 50 mc 70000V Tokyo Shibaura



iii - E-36 Kenetron 10 Amp. 20000V Tokyo Shibaura
E-35 Kenetron 10 Amp. 20000V Tokyo Shibaura



ii - E-18 Kenetron 10 Amp. 20000V Tokyo Shibaura

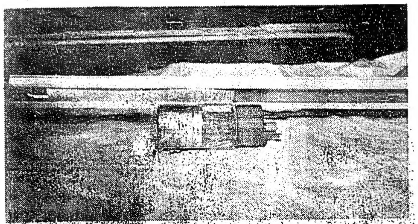


iv - E-14 Thyratron (high speed relay)

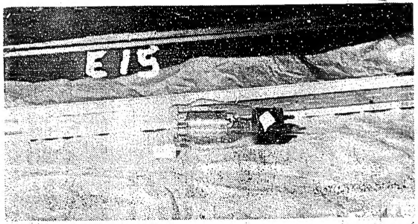
Figure 5(D)

DIODES (NINTH MILITARY TECHNICAL LABORATORY)

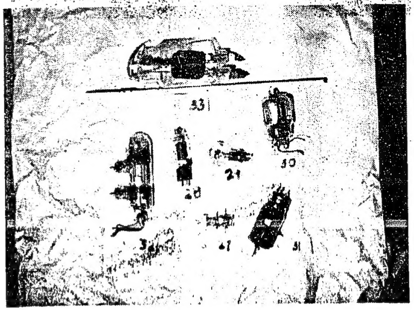
ENCLOSURE (D), continued



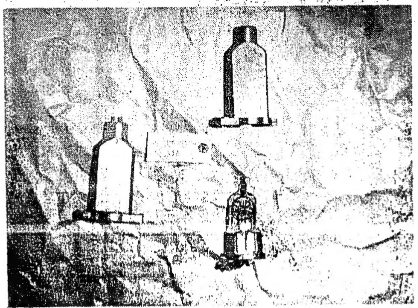
i – E-16 STV 280/40



iii – E-15 Low Voltage Discharge Tube



ii – E-27, E-28, E-29, E-30, E-31, E-32, E-41



iv – E-41 Tunable Local Oscillator Magnetron

Figure 6(D)

MISCELLANEOUS TUBES (NINTH MILITARY TECHNICAL LABORATORY)

ENCLOSURE (E)

REPRINT
"A METHOD OF PRODUCING ELECTRIC WAVES OF VERY SHORT WAVE LENGTH"
BY K. OKABE,
OSAKA IMPERIAL UNIVERSITY, 5 FEBRUARY 1941

In a reverse coupled oscillator, with the period of emission of electrons scarcely entering into consideration, oscillations of comparatively short wave length can be produced quite well by the skillful utilization of electron oscillation. However, almost no consideration is given to the period of generation of the ultra-high frequency electromagnetic field. This article states briefly how to obtain oscillations of single-stage short waves even from electron oscillation by skillful utilization of the period of generation of this ultra-high frequency electromagnetic field.

As a summary of principles, assuming that the oscillating wave flowed into the antenna or the thing corresponding to the antenna, we arranged a resonance reflecting surface so that there could be a standing wave of radiation in the space around its (antenna) circumference, also depending on the suitable flowing of electrons in this space. Part of the kinetic energy of the electrons is changed to energy of propagation, and in the end strengthens the oscillating current. In cases such as this, when ultra-high frequency oscillations are generated in the antenna (or the oscillating circuit combined with this), at one time from whatever sort of cause, if the total loss in this oscillation is not below a certain value, it is because of its original length of continuation.

Various methods have been conceived for obtaining a suitable flowing of electrons. One example of this is illustrated in Figure 1(E).

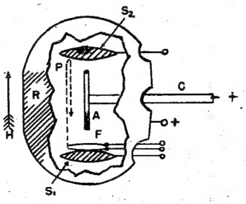


Figure 1(E)

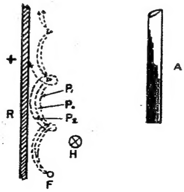


Figure 2(E)

In the diagram, A is the antenna, C is the oscillating circuit, F is the ring hot-cathode; S is the secondary electrode which is protected to a potential in the vicinty of zero, R is the resonant reflector body; H is the direction of the magnetic field, P shows the average path of the electrons.

Now if we take double the time necessary for the electron to pass through the space where the neutral process between the radiation and the super high frequency synchronization (period) T, electron synchronization (period) Te, and electrons Tf, is comparatively conspicuous, there are exceptions as regards the oscillation, but in general it is necessary that the following various relations are satisfied:

$$\left.\begin{array}{l} Te \sim nT \\ n \text{ is an odd number} \end{array}\right\} \quad (1)$$

ENCLOSURE (E), continued

$$\left.\begin{array}{l} Tf \simeq n't \\ n' \text{ is an odd number smaller than } n \end{array}\right\} \quad (2)$$

In such cases, the transfer of energy between the moving electrons and the radiation occurs alternately many times, while the electrons are flying in one direction; however, since the taking or receiving is done in the remaining time only, part of the electrons accelerate and are taken at S, part of the electrons, while slowing down with each flight, act to a certain extent in an oscillatory movement, and finally have the possibility of (are capable of generating) oscillation. This oscillation mechanism has quite a resemblance to that of the oscillation of short wave electrons.

Figure 2 is the case in which the decelerating electron does not conduct oscillatory movement, and only part of the arrangement is shown in the diagram. The symbols have the same meaning as in Figure 1. However, Po shows the path of the electron in the case where there is no influence of radiation, P_1 shows the path of the decelerating electron, P_2 shows the path of the accelerating electron. Since the accelerating electron is quickly taken to R, there is the possibility of final oscillation. However, it is necessary that roughly the following relations be satisfied between super high frequency synchronization T, and electron synchronization (the time necessary for the electron to describe the semi-circular path one time) Te'.

$$\left.\begin{array}{l} Te' \simeq n''T \\ n'' \text{ is an odd number } 1,3,5 \end{array}\right\} \quad (3)$$

If a strong circular magnetic field can be established around A, that is fine; but since that is difficult in actual practice, it becomes necessary to limit the place of transfer of energy to a part of it (the field).

Various other methods have been devised; however, no matter which one is used, it is believed that one more step in research and planning is still necessary as regards the realization of an oscillator such as is proposed here. This article goes no farther than simply pointing out that the realization of this type of oscillator is to a certain extent theoretically possible.

However, if it were possible to have an oscillator depending on the mutual interaction between moving electrons and ultra-high frequencies, it would be by means of the utilization of the same principle, whether it be a natural ultra-high frequency amplifier, or whether it be an amplifier detector. However, these are believed to belong to the problems of the future.

In conclusion, I wish to express gratitude for the assistance of the Japanese Association for the Advancement of Science, the instruction of Professor HACHIKI, and the discussion and instruction of all the members of the Number One Subcommittee for the Second Sectional Committee of the Japanese Association for the Advancement of Science.